STUDY OF VOLTAGE SAG IN POWER SYSTEM WITH SIX-PHASE TRANSMISSION LINE

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"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Power System)"

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To my beloved mother, father, sisters, and brother

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ABSTRACT

Voltage sags are the short durations in root-mean-square (RMS) rated AC voltage occur during faults may cause miss-operations to the customer’s equipment and loads of power system and recognized as the most important power quality problem. However, this thesis investigate the sag event which is caused by short circuit (three-phase-to-ground fault and six-phase-to-ground fault) on the double three phase transmission line and conversion of phase double circuit to the six phase single circuit transmission line. Six phase were chosen for this project because six phase enhance power transfer capability and becoming the area of growing interest in the power system industry. This thesis also presents the comparisons between voltage reductions at the terminal bus for both three and six phase cases. Simulation at steady state and transient state of the system proposed is simulated using PSCAD/EMTDC. The system that used in this thesis was four buses transmission line. The simulation result shows that converted double three phase to six phase transmission experienced lower voltage sags level at other bus terminal than double three phase system due to three-phase-to-ground fault and six phase-to-ground fault if the fault happen at bus three, but for faulted bus, the it’s experienced the same percentage voltage sag. For fault happen between transformers in six phase operation, 20% to 45% of the voltage was improve at the faulted bus compare to three phase system.

ABSTRAK

Kejatuhan voltan diklasifikasikan sebagai voltan purata punca kuasa dua yang berlaku dalam masa yang singkat ketika gangguan elektrik yang menyebabkan peralatan pengguna dan beban pada bekalan kuasa tidak berfungsi sepenuhnya dan juga dikenali sebagai faktor utama masalah gangguan bekalan kuasa. Walaubagaimanapun, tesis ini menyelidiki gangguan yang berlaku yang disebabkan oleh litar pintas pada talian penghantaran berkembar tiga fasa dan talian bekembar tiga fasa yang diubahsuai kepada talian penghantaran enam fasa. Talian penghantaran enam fasa dipilih dalam projek ini kerana sistem enam fasa meningkatkan penghantaran bekalan kuasa dan menjadi salah satu pilihan utama yang sedang dikaji untuk dibangunkan dalam industri bekalan kuasa. Tesis ini juga membandingkan perbezaan kejatuhan voltan pada terminal bas untuk kedua-dua sistem tiga fasa dan enam fasa. Simulasi pada keadaan mantap dan keadaan fana pada sistem yang telah dipilih dikendali menggunakan perisian komputer PSCAD/EMTDC. Sistem yang digunakan dalam tesis ini adalah sistem penghantaran 4 bas. Keputusan simulasi menunjukkan talian berkembar tiga fasa yang siubahsuai kepada talian enam fasa mengalami kejatuhan voltan yang randah pada terminal bas yang lain jika dibandingkan dengan talian berkembar tiga fasa yang disebabkan oleh litar pintas tiga fasa ke bumi dan litar pintas enam fasa ke bumi yang berlaku pada bas tiga. Pada bas yang berlaku litar pintas, peratusan kejatuhan voltan pada kedua-dua sistem talian adalah sama. Pada litar pintas yang berlaku di antara pengubah bagi sistem enam fasa, 20% to 45% voltan meningkat pada bas yang mengalami litar pintas berbanding system tiga fasa.

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LIST OF SYMBOLS

P	-	Real Power
Q	-	Reactive Power
S	-	Apparent Power @ Complex Power
V	-	Voltage
V_{Phase}	-	Phase Voltage
$V_{Line-Line}$	-	Line Voltage
I	-	Current
I_{Phase}	-	Phase Current
$I_{Line-Line}$	-	Line Current
δ	-	Phase Angle
Z	-	Impedance
b	-	Line Charging
X @ x	-	Reactance
X_L	-	Inductive Reactive
X_C	-	Capacitive Reactance
F	-	Frequency
L	-	Impedance
C	-	Capacitance
R @ r	-	Resistance
s	-	Second
pu @ p.u	-	Per-Unit

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CHAPTER 1

INTRODUCTION

1.0 Power Quality

Power Quality is a simple term, yet it's describes a multitude (a large number of people or things) of issues that are found in electrical power system and is a subjective term [6]. Power quality is actually the quality of the voltage that is being addressed in most cases. The standards in power quality area are devoted to maintaining the supply voltage within the certain limits [7].Power quality disturbances such as momentary under-voltage (sag), over-voltage (swell), surges and harmonics have been identified as the major sources of power quality problems. For example, momentary under-voltage (sag); voltage sag can cause sensitive equipment to trip thus effecting industrial production losses. Such occurrences have major economic impact as well as impact on the quality of product and services [2].

Power quality is a new whole area within electrical engineering where fundamental research involves basic concept and definitions; modeling and analysis; measurement and instrumentation; sources; effect; and mitigation. The ultimate goal of power quality research is to maintain a satisfactory quality of electric supply.

1.1 Power Quality Disturbance

Depending upon the effects, causes and nature of disturbances, power quality disturbances can be classified according to their characteristics. According to IEEE Std. 1159-1995, the power system disturbances may consists of transients, short duration variation, momentary, temporary, long duration variations, voltage imbalance, waveform distortion, voltage fluctuation and power frequency variation. Section 1.2.1 gives an overview of classification of power quality disturbances while Table 1.1 described the causes and effect of power quality disturbances.

1.1.1 Classification of Power Quality Disturbances

1) ***Sags***: momentarily short duration (0.5-30 cycles) decrease of the rated voltage (0.1-0.9pu)
2) ***Swells***: Momentarily short duration (0.5-30 cycles) increased of the rated voltage (1.1-1.8pu)
3) ***Transients***: High amplitude, short duration (<0.5 cycle) voltage disturbances.
4) Voltage unbalance: variation of magnitude and/or phase angle from different phase.
5) ***Harmonics***: voltage and/or current deviation from a true sin wave due to unwanted frequencies that are multiples of fundamental waves.
6) ***Frequency deviation***: a variation of frequency from 60Hz (e.g. caused by the starting of heavy loads on weaker generator systems).
7) ***Flicker***: refer to repetitive sags or swells.
8) ***Spikes***: in phase impulses which increased the instantaneous voltage.
9) ***Voltage deviation***: a long term charge above (over-voltage) or below (under-voltage) the prescribed normal voltage range.
10) ***Blackout***: refer to a total loss of input voltage for a few cycles or more.

Table 1.1: Causes and Effects PQ Disturbances

Disturbances	**Typical Causes**	**Effect**
Sags and Swells	Fault, Motor starting, lightning strike	Computer system interruptions, motor staling
Transients	Load, Lightning, Capacitor switching	System Overvoltage, insulation failures, malfunction of sensitive electronic devices
Harmonic Distortion	Power Electronics, arching device, Saturable Device	Capacitor blowing, Transformer Heating/failure, breaker nuisance trips, protective relaying errors

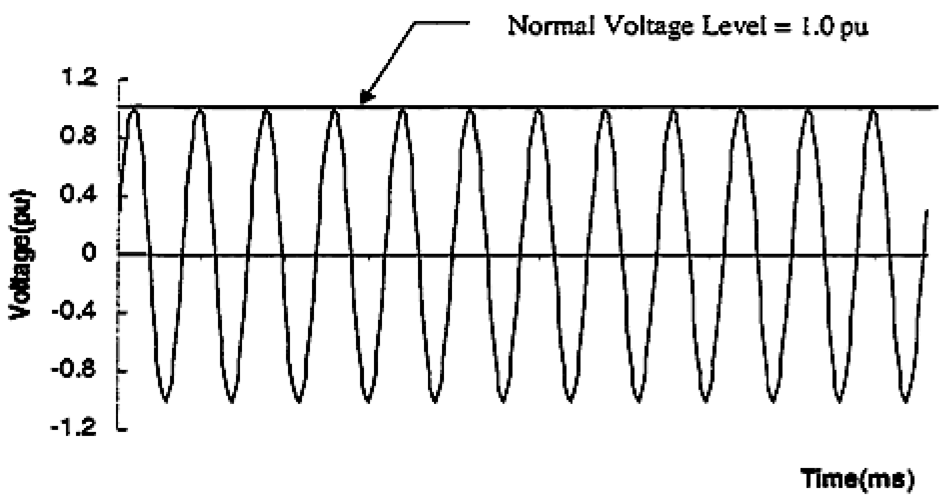

Figure 1.1: Normal Voltage Waveform

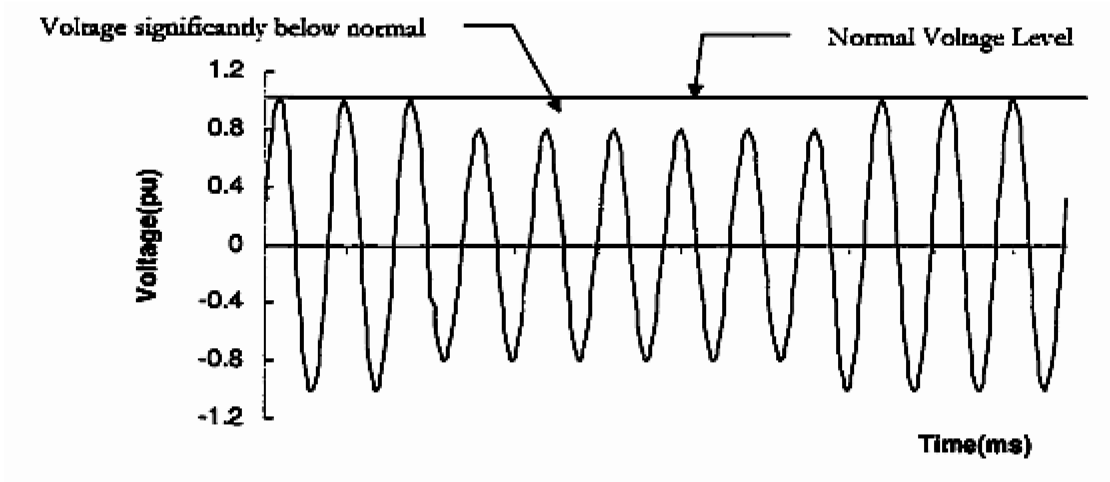

Figure 1.2: Voltage-Sag Waveform

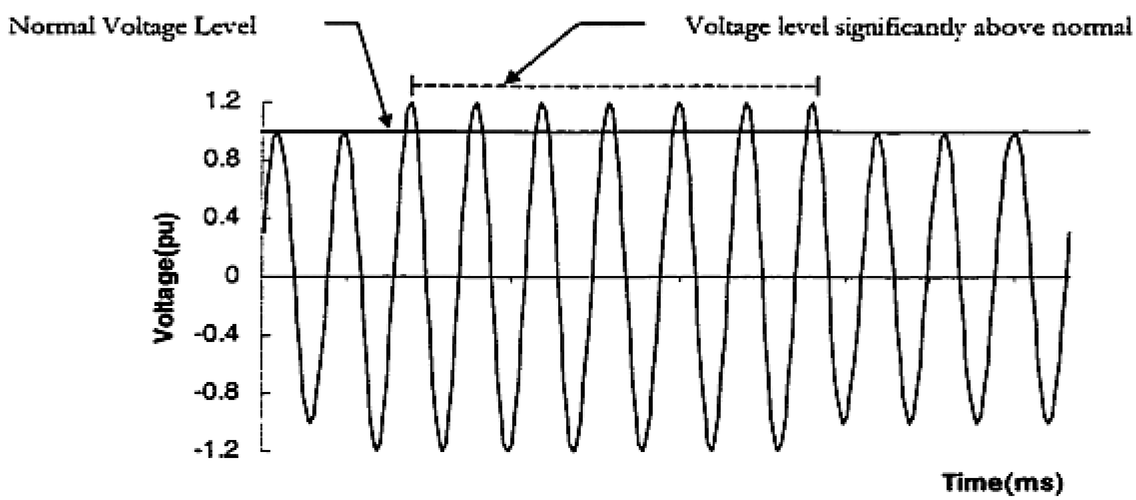

Figure 1.3: Voltage-Swell Waveform

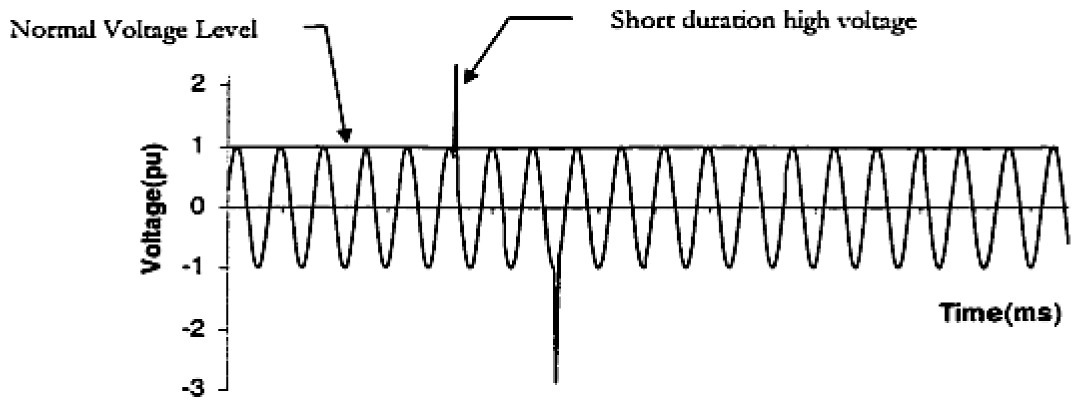

Figure 1.4: Voltage-Surge Waveform (Transient)

Figure 1.1 to Figure 1.4 shows the sample waveform of normal voltage, voltage sag, voltage swell and voltage Surge respectively. For normal voltage waveform in Figure 1.1, let us consider the per-unit value was 1.0 p.u. Figure 1.2 shows waveform during sag event, voltage waveform shows waveform significantly below normal voltage level. If the voltage waveform is significantly above normal voltage level as shown in Figure 1.3, this type of event was consider as voltage swell. Figure 1.4 was consider as transient event or also called as voltage spike or surge which happen over every short time. This short time interval is less than 1 cycle.

1.2 Literature Review

Voltage sags are momentary dips in voltage magnitude that can cause sensitive equipment to trip. It is recognizing as the most important power quality problem that affecting industrial customers thus affecting industrial production losses. Therefore the study of voltage has become a major effort at many electrical utilities and industrial customer worldwide [2]. Single line to ground fault had been discussed in [3] to determine the origin of the fault that lead to the voltage sag event. For the study, fault were simulate at the one place while monitor the sag happen at other buses. Fault was simulated as mention above involving fault impedance and without fault impedance. For the validation of the procedure, Malaysian utility, Tenaga Nasional Berhad's transmission and distribution network were used. However, the effectiveness of the method was depending on the accuracy of the network impedance.

Another study of voltage sag is the analysis on the distributed generation (DG) by looking the impact on the voltage sag [4]. This study analyzed the characteristics of voltage sag in distribution network that caused at transmission level by present of DG. The analysis continues by study the percentage of voltage drop before and after DG existence. When fault were apply at transmission line; HV side, the effect at the MV were analyzed. Since reactive power very sensitive to voltage, the flow and effect of the reactive power was taking into consideration. Thus this paper has proved that, DG has a positive impact on the characteristics of the voltage sags caused at any level.

Since future growth of power systems will rely more on increasing capability of already existing transmission systems, rather than on building new transmission lines and power stations, for economic and environmental reasons, thus six phase transmission appears to be the best solution to the need to increase the capability of an existing transmission line. Also at the same time, respond to the concern relating to the economical and environmental effect [5].

1.3 Objectives

The objectives of this project can be list as below:

1. To understand power system network that consists of six-phase transmission line

2. To present simulation of load flow and fault at electrical test system

3. To recognize the effects of fault location on voltage sag

1.4 Scope of Work

Scopes of this project are to:

1) Power Flow Analysis

Power flow analysis is the first part of the project. The analysis was present for the three bus and four bus system.

2) Modeling of the system

Modeling of three-phase and six-phase transmission was modeled for four buses. The construction of six phase transmission will be discussed in detail; transformer connection. These modeling will be used for simulation studies of voltage sags.

3) Simulation studies of Voltage Sag due to fault

Short circuit fault simulation will be present in this study. The fault will be between three phases-to-ground and six phase to ground is illustrated here. This is because, one of the causes of voltage sag is fault at the system whether transmission or distribution; symmetrical or unsymmetrical fault, with or without fault impedance.

4) Analyze the Limitation of voltage sag in six phase transmission line

All the data obtained from the simulation will be collect and analyzed here. These analyses were due to the four busses. These data will be present in table and graph for of the voltage sag. The data obtained will be useful for system design, equipment selection, etc.

1.5 Report Structure

The work in this thesis involves five chapters. The first chapter was the introduction of this thesis. Second chapter review an introduction for six phase and voltage sag. This chapter is to observe and identify characteristics of voltage sag causes, characteristics, its magnitude and duration. For six-phase transmission, this chapter gives an overview of six-phase and also with the benefit of using six-phase transmission line compare to three phase transmission line.

Chapter three based on modeling power system component of three-phase and six-phase transmission with elaboration of its transformer connection to construct six phase transmission line, using four busses system modified from the IEEE standard system data. This modeling was constructing using PSCAD/EMTDC software. In Chapter 4, the simulation studies of power flow analysis and voltage sag were present using modeling from the previous chapter. Sag data were collect in this chapter after the simulation and discussed. Lastly, Chapter 5 concludes the whole thesis and future recommendation also be discussed here.